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(54) HELICOPTER ROTORS

(71) We, WESTLAND AIRCRAFT LIMITED, of Yeovil, in the County of Somerset, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to helicopter rotors.

In helicopter rotors, all thrust and centrifugal loads produced by rotation of the rotor blades are transmitted to a fuselage through a rotor hub structure that is also conveniently utilised to support means to enable the rotor blades to perform necessary flap, lead/lag and feathering movements during operation.

The rotor hub is, therefore, a critical component, and adequate strength considerations have in the past resulted generally in very heavy and unwieldly structures. Even so, frequent maintenance inspections are necessary to ensure the integrity of the rotor hub structure and, since such inspections can comprise only visual checks with the rotor hub in situ, removal and disassembly of the rotor hub is necessary to complete the more thorough inspections required. Apart from being a very time consuming and expensive task, this also means of course that the helicopter is grounded while such inspections are taking place.

It is, therefore, an object of the present invention to provide a helicopter rotor, in which maintenance and servicing requirements are minimised.

Accordingly, in one aspect, the invention provides a helicopter rotor including a rotor hub supporting a plurality of rotor blades for rotation about an axis, the rotor hub comprising a sealed hollow structure having a central portion rotationally fixed to a rotor drive shaft, means supporting each rotor blade so that said rotor blade is capable, during operation, of flap, lead/lad and feathering movements, means for introducing a pressurised gas into said hollow hub structure, and pressure responsive indicator means arranged to provide an indication of any loss of gass pressure from said hub structure.

Preferably the hollow hub structure comprises a titanium casting.

The central position may comprise a tubular portion located concentrically of the rotational axis, and may include splines engaged in mating splines on the rotor drive shaft.

A plurality of generally tubular arms equal in number to the number of rotor blades may be arranged to extend outwardly from the tubular central portion and, conveniently, the means supporting each rotor blade may be located within its respective arm.

Side walls of adjacent arms may be coextensive and may extend in a substantially continuous curve from an outer end of one arm to an outer end of the adjacent arm. The side walls may be spaced-apart from the tubular central portion and may be joined thereto by apertured webs located between each adjacent pair of arms.

A domed cover may be secured to an upper surface of the hub structure generally concentrically with the axis of rotation.

The means for introducing a pressurised gas may comprise a gas charging valve, and the gas pressure responsive means may comprise a visual gas pressure indicator, and the valve and indicator may be secured on one, or separate ones of the plurality of arms.

In one form of the invention, the gass pressure indicator may, conveniently, comprise an indicator of known kind that includes a transparent casing provided with a plurality of non transparent circumferential stripes and an inner member provided with similar stripes and being axially mov-

able under the influence of gas pressure in the hollow hub structure.

Alternatively, the gas pressure responsive means may comprise a gas pressure operated switch that may be connected electrically to a suitably located warning device.

The rotor drive shaft may be tubular, and may be provided with means for sealing upper and lower ends thereof and means for introducing a pressurised gas into its interior. A tube may be sealingly supported within the tubular motor drive shaft and may be arranged concentrically so as to provide a passage through the shaft, through which essential services can be routed to the rotor, and an annular space between an outer surface of the tube and a bore of the drive shaft.

Conveniently the means for introducing pressurised gas into the hollow shaft comprises a passage providing communication between the interior of one of the hollow arms and the annular space in the rotor drive shaft. In such an installation, the pressure responsive indicator means serves to provide an indication of the integrity of both the rotor hub structure and the drive shaft. Alternatively, the annular space may be separate from the interior of the hollow structure, in which case separate changing and indicator means may be provided for communication with the annular space.

Preferably, the means for supporting each rotor blade from its respective arm comprises an elastomeric bearing assembly. Each assembly may include conical and spherical elastomeric bearing units interconnected by a tubular support and located about a common focal point. Conveniently, the elastomeric bearing assembly is sealingly attached within each arm through a flange bonded to one end of the assembly and attached to an outwardly facing surface of its respective arm.

A rotor blade support spindle may be rotationally fixed to the elastomeric bearing assembly and may be located within the tubular support so as to protrude from an outer end of its respective arm, and an outer end of the support spindle may be provided with means for attachment of the rotor blade. An inner end of the spindle may be operatively associated with lead/lad damping means and rotor blade droop stop means located entirely within the hollow hub structure.

The rotor blade attachment means may include a hinge pin and. power operated means may be provided so as to pivot the rotor blade about the hinge pin between operational and folded positions.

Preferably, the power operated means is housed within an outer tubular end of the blade support spindle and comprises a hydraulically operated acuator. The actuator may include a casing supported on low friction bearings in the tubular end of the support spindle so as to be capable of relative axial movement and a piston extending from an outer end of the casing for operative association with the hinge pin.

An inner end of said casing may carry an arcuate lever extending through slots in the tubular support spindle, and outer ends of the lever may be arranged to contact an outwardly facing surface of the arm at diametrically opposed positions on axial movement of the casing during certain phases of operation so as to centralise the rotor blade during folding movement and to locate the blade when in its folded position.

Preferably, the lever is located in a plane generally parallel to a plane of rotation of the rotor.

In another respect the invention provides a helicopter rotor including a rotor hub supporting a plurality of rotor blades about a generally vertical axis, the rotor hub comprising a sealed hollow structure having a central portion rotationally fixed to a rotor drive shaft and a plurality of generally tubular arms extending outwardly from the central portion and equal in number to the number of rotor blades, an elastomeric bearing assembly located within each arm to support its respective rotor blade so that the rotor blade is capable, during operation of flap, lead/lag and feathering movements, a gas charging valve attached to the rotor hub and in communication with the interior thereof so as to enable the hub structure to be pressurised, and a gas pressure indicator attached to the rotor hub and arranged to provide a visual indication of any loss of gas pressure from the hub.

The invention will now be described by way of example only and with reference to the accompanying drawings, in which:–

Figure 1 is a fragmentary part sectioned view taken along lines A–A of Figure 1, and

Figures 3 to 5 inclusive are fragmentary sectioned views similar to Figure 2, each illustrating a further embodiment of the invention.

Figure 2 is a fragmentary part sectioned view taken along lines A–A of Figure 1,

Referring now to Figures 1 and 2 a helicopter rotor includes a rotor hub 11 supporting a plurality of rotor blades 12 (one only being illustrated) for rotation about a vertical axis 13 in the direction of arrow B. A root end only of rotor blade 12 is shown in the drawings.

The rotor hub 11 is an integral structure comprising a hollow titanium casting having a tubular central portion 14 and a plurality of outwardly extending generally tubular arms 15 equal in number to the number of rotor blades 12. Side walls 16 of adjacent arms 15 are co-extensive and extend in a

generally continuous curve from an end of one arm 15 to an end of two adjacent arms 15. The walls 16 are spaced-apart from the central portion 14 and are joined thereto by a plurality of apertured radially extending webs 17 between each arm 15.

The apertured webs 17 ensure free communication between the interior of all of the hollow arms 15 within the hub structure 11.

A gas charging valve 47 and a gas pressure indicator 48 are arranged to communicate with the interior of one of the hollow arms 15 for a purpose to be hereinafter explained. The valve 47 and indicator 48 are screwed into threaded bosses provided on the hollow arm 15 at generally diametrically opposed positions so that both the valve 47 and the indicator 48 lie in the plane of rotation of the rotor hub 11.

In the embodiment illustrated in Figure 1, the gas pressure indicator 48 is of a known type that comprises a transparent casing provided with a plurality of non transparent circumferential stripes and an inner member provided with similar stripes and axially movable within the casing under the influence of gas pressure.

A sleeve 18 is secured in the tubular portion 14 and is rotationally fixed to a hollow rotor drive shaft 49 through mating splines 19.

Services, such as necessary electrical and hydraulic supplies (not shown) are routed upwardly through the hollow shaft 49. The services are routed to the outer end of each arm 15 either externally of the arm 15 or through suitable passageways (not shown) incorporated in the casting.

A domed cover 50 is located centrally of the axis 13 and is sealingly secured to the hub 11 by a ring of bolts.

An elastomeric bearing assembly, generally indicated at 20, is located in each arm 15. Each bearing assembly 20 includes a spherical and a conical elastomeric bearing unit 21 and 22 respectively, interconnected through a tubular support 23. The bearing units 21 and 33 have a common focal point 24.

Each elastomeric bearing assembly 20 is secured to its respective arm 15 through a flange 25 bonded to the spherical bearing unit 21 and bolted to an outwardly facing surface of the arm 15, the attachment including suitable sealing means (not shown) to ensure a gastight seal.

An inner end of a tubular blade attachment spindle 26 is secured at the other end of the bearing assembly 20, and is located through the tubular support 23 to protrude from the end of the arm 15. The spindle 26 terminates in an outer end arranged for attachment of the rotor blade 12 through a blade fold hinge pin 27.

A shear bearing 46 is located between the spindle 26 and the interior of the tubular bearing support 23 to prevent interaction of the parts during normal movements of the rotor blades 12 encountered during operation.

Inner end of spindle 26 is secured through a spacer 28 mounted on splines on the spindle 26 and secured by a retaining nut 29. Additionally, a cover 30 is located on a squared section 31 formed on the spindle and has an annular flange which is bolted, together with the spacer 28, to a ring member 32 bonded to the conical elastomeric bearing 22.

An extension of the spindle 26 provides a mounting for a rotatably mounted bearing 33 retained by a nut. The bearing 33 has an extending lug 34 that provides attachment for one end of a lead/lad damper 35, preferably of the elastomeric type. The other end of the damper 35 is bolted to a lug 36 formed on the inner surface of the walls 16 so as to be located through the aperture in the webs 17 and generally tangentially to the central portion 14.

A fork end 37 extends from a boss on the central portion 14 between each web 17, and pivotally supp[illegible] a quadrant shaped droop stop lever 38 [illegible]out a generally horizontal axis, so that one of its edges contacts the bearing 33 during certain phases of operation and its other surface contacts a rigid droop stop ring 39 resiliently mounted on rubber mountings (not shown) attached to each web 17.

Externally of the arms 15, the outer protruding end of the spindle 26 comprises an enlarged tubular portion 51 housing a hydraulically operated blade fold actuator 40 (Figure 2). The actuator includes a casing 41 supported on low friction bearings 42 to permit axial movement, and a piston 43 pivotally connected to inwardly directed flanges at the root end of the blade 12. Alternatively, the piston 43 could be connected to another form of blade fold mechanism which may include meshing quadrant gears, oen of which is fixedly attached to the hinge pin 27.

An inner end of the casing 41 carries an arcuate lever 44 extending through suitable slots 45 in the spindle 26 in a plane generally parallel to the plane of rotation, and arranged so that during certain phases of operation the ends of the lever 44 contact an outer surface of the flange 25 at diametrically opposed positions.

A blade pitch control lever 65 is secured to a flange on the spindle 26 and is connected to a flying control system (not shown).

From figure 1 it will be clear that the axis of the spindle 26 and therefore the blade 12 is offset from the axis of rotation 13 of the hub. The location of the focal point 24 of the

elastomeric bearing assembly 20 determines this offset and, in the embodiment shown, this is located at a position corresponding approximately with 5 per cent of the rotor blade radius measured from the axis 13. However, the arrangement of the present invention facilitates variations in this position to suit the necessary control response requirement of different installations.

In the embodiment illustrated in Figure 3, a tube 52 is supported co-axially in the drive shaft 49 so as to provide an annular space 53 between an outer surface of the tube 52 and a bore of the shaft 49. The tube 52 provides a passage for necessary services to the rotor in this embodiment, and is supported at its upper and lower extremities by flanged attachment members 54 and 55 respectively. Suitable gas pressure seals 56 are provided at each end of the tube 52, and a gas pressure seal 57 is located at a lower end of the sleeve 18.

The annular space 53 communicates with a chamber 58 at the upper end of the drive shaft 49, that, in turn, communicates through passageway 59 in the sleeve 18 and central portion 14 with the interior of one of the hollow arms 15.

Figure 4 illustrates an alternative embodiment in which the annular space 53 is sealed separately from the interior of the arm 15. In this arrangement, an additional gas charging valve 60 and gas pressure indicator 61 are screwed into the lower protruding end of the drive shaft 49 to communicate with the space 53.

In Figure 5, a hollow rotor drive shaft 62 has an upper flange portion 63 that is drivingly connected to the rotor hub 11 through a ring of bolts screwed into corresponding threaded bosses provided on the hub 11. Suitable sealing means (not shown) are provided in the bolted attachment. A tube 52 is again supported in the hollow shaft 53 communicates through passageway 64 in the central portion 14 with the interior of one of the arms 15.

In operation of the helicopter rotor of the present invention, the provision of the hollow hub structure 11 in which the blade support bearings, lead/lag dampers and the blade droop stop mechanism vu housed, results in an aerodynamically clean design with a low drag penalty. Also, the parts are protected from the ingress of dust, dirt and moisture, thereby ensuring freedom from contamination and damage to enhance the service life of the rotor.

Referring now particularly to Figures 1 and 2, it will be apparent that incorporation of the single elastomeric bearing assembly 20 facilitates efficient sealing at the end of each arm 15 to retain a gas pressure within the hollow hub structure 11.

Pressurised gas is introduced into the interior of the hub structure 11 through the charging valve 47 in one of the arms 15, and circulates to fill the entire hollow structure 11 through the apertures in webs 17. The gas, at a pressure of 10 p.s.i (i.e. about 24 p.s.i. absolute) may be air although, preferably, dry nitrogen is used so as to prevent internal corrosion.

The pressure of the gas acts on the indicator 48 so that the stripes on the casing and the inner member are aligned. In the event of any reduction in gas pressure caused, for instance, by a crack in the hub structure 11, the inner member in the indicator 48 will move axially so that the stripes are offset from those in the casing, thereby providing an immediate visual indication, so that any failure in the hub structure 11 is immediately visible during routine service inspections.

It has previously been proposed to utilise a similar method to check the integrity of hollow spar members in helicopter rotor blades, and one such a system has become known in the art as the Blade Inspection Method.

It will be apparent, therefore, that by providing a hollow hub structure that results in aerodynamic and other advantages, the present invention extends this facility to provide a quick and efficient check on the integrity of the hub structure itself. Thus, when used on a helicopter incorporating the Blade Inspection Method, the present invention provides a simultaneous Hub Inspection Method that represents an extension of accepted inspection and service principles with which appropriate personnel will be readily conversant.

The present invention, therefore, provides important advantages in significantly reducing routine inspection and servicing requirements, and improving the safety aspect of helicopter operations.

In this latter respect it will be noted that the indicator 48 might be replaced by, or be in addition to, a pressure indicator in the form of a gas pressure responsive switch that may be connected electrically onto a centralised warning panel. Such a panel may, conveniently, be located in a pilot's cabin and arranged to provide a visual and/or audible warning in the event of any loss of gas pressure from the hub during flight.

In the embodiment of Figure 3, the inspection facility is extended to include the hollow rotor drive shaft 49. Thus, on pressurising the hub structure 11, the pressurised gas flows through the passage 59 to fill the annular space 53, thereby providing an immediate visual check of the integrity of both the hub structure and the rotor drive shaft on the one externally positioned indicator 48 (Figure 2).

A separate facility is provided in Figure 4

to check the integrity of the hollow rotor drive shaft 49. The annular space 53 is filled with pressurised gas through an additional charging valve 60 and indication is provided by an additional indicator 61. The valve 60 and indicator 61 are shown located in a protruding lower end of the drive shaft 49, although it will be apparent that they could be located at any other convenient position that provides a ready access.

Figure 5 illustrates an alternative connection between the hub structure 11 and a hollow rotor drive shaft 62. Again, in this embodiment, the hub inspection facility is extended to include the drive shaft 62 by the provision of passage 63 in the central portion 14 that ensures the flow of pressurised gas into the seal annular space 53.

Referring again to Figures 1 and 2, centrifugal loads encountered during operation are transmitted to the hub 11 through the elastmoeric bearing units 21 and 22 which are relatively stiff in compression, and blade flap and lead/lag movements are permitted by twisting of the bearings about the focal point 24. Rotor blade pitch changes, initiated through the lever 65, are permitted by torsional motions through both bearing units 21 and 22 in series, thus reducing the overall torsional stiffness to an acceptable level. The pitch change movements are transmitted to the bearing units through both the splined spacer 28 and the cover 30, although the cover 30 is not essential in this respect.

Lead/lag motion is damped by the dampers 35 which are attached to the spindle 26 at a position approximately 6.7 inches inboard of the focal point 24. Whereas elastomeric dampers have been proposed it is to be understood that other suitable types, for instance, hydraulic dampers could be used.

When the rotor is stopped, blade droop is limited by collective contact of the bearings 33 via the levers 38 onto the ring 38 which is in compression. In normal flight individual blade droop is not restricted, the ring 39 being displaced laterally on its rubber mountings when contacted from one point only.

When it is desired to fold the blades 12 to a stowed position the rotor is suitably positioned, and flying control jacks are locked at a predetermined swash plate setting, thereby ensuring that individual blades fold on the correct plane for clearance purposes. Torsional loads on the pitch change axis applied by the xlade during folding are reacted by the jacks through the pitch control arm.

Rotor blade lock pins (not shown) are released.

Initial energisation of each hydraulic actuator 40 to fold the blades 12 by extension of the piston 43 moves the actuator casing 41 axially in the bearings 42 towards the hub structure 11. This movement causes the ends of the arcuate lever 44 to be loaded against the surface of the flange 25, as shown in Figure 1, thereby reacting the axial load of the blade 12 through the hub 11 to centralise the blade 12 and hold it positively during and after folding about the hinge pin 27. It will be apparent that this load is automatically released during spreading of the blades 12, to facilitate normal movements of the blades during flight.

A problem that has tended to preclude the use of elastomeric devices in helicopter rotors, especially if operation in extremely low temperatures is envisaged, concerns a tendency of such devices to become progressively harder and therefore more stiff on decrease of surrounding temperature, altering their operational characteristics. This is particularly important, in respect of elastomeric dampers in that it could result, at start-up in a pehenomenon known as ground resonance which may cause serious damage to the machine.

The arrangement of the present invention, in which the bearings and damper are enclosed within the hollow sealed hub structure, facilitates a solution to this problem. Thus, means for pre-heating the elastomeric devices such as electrically operated heating elements can readily be incorporated within the hollow hub structure 11, and can be connected, along with other essential services, through the hollow rotor drive shafts of the various embodiments of the invention hereinbefore described.

WHAT WE CLAIM IS:–

1. A helicopter rotor including a rotor hub supporting a plurality of rotor blades for rotation about an axis, said rotor hub comprising a sealed hollow structure having a central portion rotationally fixed to a rotor drive shaft, means supporting each rotor blade so that said blade is capable, during operation, of flap, lead/lag and feathering movements, means for introducing a pressurised gas into said hollow hub structure, and pressure responsive means arranged to provide an indication of any loss of gas pressure from the interior of the hub structure.

2. A rotor as claimed in claim 1, wherein said sealed hollow rotor hub structure comprises a titanium casting.

3. A rotor as claimed in claim 1 or claim 2, wherein said central portion comprises a tubular portion located concentrically of said axis of rotation and including splines engaged in mating splines on the rotor drive shaft.

4. A rotor as claimed in any preceding claim, wherein a plurality of generally tubular arms equal in number to the number of rotor blades extend outwardly from said central portion.

5. A rotor as claimed in claim 4, wherein side walls of adjacent arms are co-extensive and extend in a substantially continuous curve from an outer end of one arm to an outer end of its adjacent arm.

6. A rotor as claimed in claim 5, wherein said side walls are spaced-apart from said central portion and are joined thereto by apertured webs located between each adjacent pair of arms.

7. A rotor as claimed in any preceding claim, wherein a domed cover is secured to an upper surface of the hub generally concentrically of said axis of rotation.

8. A rotor as claimed in any preceding claim, wherein said means for introducing a pressurised gas into the hollow hub structure comprises a gas charging valve.

9. A rotor as claimed in claim 8 when dependent from any one of claims 4 to 7 wherein said gas charging valve is secured on one of said arms.

10. A rotor as claimed in any preceding claim, wherein said gas pressure responsive means comprises a visual gas pressure indicator.

11. A rotor as claimed in claim 10 when dependent from any one of claims 4 to 9, wherein said visual gas pressure indicator is secured on one of said arms.

12. A rotor as claimed in claim 10 or 11, wherein said gas pressure indicator includes a transparent casing provided with a plurality of non transparent circumferential stripes, and an inner member provided with similar stripes and being axially movale under the influence of the pressure of gas in said hollow hub structure.

13. A rotor as claimed in any one of claims 1 to 9 inclusive, wherein said gas pressure responsive means comprises a gas pressure operated switch.

14. A rotor as claimed in claim 13, wherein said gas pressure responsive switch is electrically connected to a warning device.

15. A rotor as claimed in any preceding claim, wherein said rotor drive shaft is tubular, and including means for sealing upper and lower ends of the shaft and means for introducing a pressurised gas into the interior of the shaft.

16. A rotor as claimed in claim 15, wherein a tube is sealingly supported at its extremities within the tubular rotor drive shaft, said tube being arranged concentrically so as to provide a passage through the shaft and an annular space between an outer surface of the tube and a bore of the drive shaft.

17. A rotor as claimed in claim 16, wherein said means for introducing pressurised gas comprises a passage providing communication between the interior of said hub structure and said annular space in said rotor drive shaft.

18. A rotor as claimed in claim 16, wherein said means for introducing pressurised gas comprises a gas charging valve secured in the rotor drive shaft in communication with said annular space, pressure responsive means being provided to give an immediate indication of any loss of gas pressure from said space.

19. A rotor as claimed in any one of claims 4 to 18, wherein said means for supporting each rotor blade comprises an elastomeric bearing assembly within a respective one of solid arms and including a conical and a spherical elastomeric unit interconnected by a tubular support and located about a common focal point.

20. A rotor as claimed in claim 19, wherein said elastomeric bearing assembly is sealingly attached to each arm through a flange bonded to one end of said bearing assembly and attached to an outwardly facing surface of its respective arm.

21. A rotor as claimed in claim 19 or claim 20, including a blade support spindle rotationally fixed to said elastomeric bearing assembly within said tubular support so as to protrude from an end of its respective arm, an outer end of said support spindle being provided with means for attachment of said rotor blade.

22. A rotor as claimed in claim 21, wherein an inner end of said blade support spindle is operatively associated with lead/lag damping means and rotor blade droop stop means located within the hollow hub structure.

23. A rotor as claimed in claim 21 or claim 22, wherein said blade attachment means includes a hinge pin, power operated means being provided so as to pivot said rotor blade about the hinge pin between operational and folded positions.

24. A rotor as claimed in claim 23, wherein said outer end of the blade support spindle is tubular and is arranged to house said power operated means.

25. A rotor as claimed in claim 24, wherein said power operated means comprises a hqdraulically operated blade fold actuator.

26. A rotor as claimed in claim 25, wherein said actuator includes a casing supported on low friction bearings in said tubular outer end of the blade support spindle, so as to be capable of axial movement within said tubular end, and a piston extending from an outer end of said casing for operative association with said hinge pin.

27. A rotor as claimed in claim 26, wherein an inner end of said axially movable casing carries an arcuate lever extending through slots in said tubular end of the blade support spindle, outer ends of the lever being arranged so as to contact an outwardly facing surface of said arm at diametrically

opposed positions on axial movement of the casing during certain phases of operation.

28. A rotor as claimed in claim 27, wherein said lever is located in a plane generally parallel to a plane of rotation of the rotor.

29. A helicopter rotor including a rotor hub supporting a plurality of rotor blades for rotation about a generally vertical axis, said rotor hub comprising a sealed hollow structure having a central portion rotationally fixed to a rotor drive shaft and a plurality of generally tubular arms extending outwardly from the central portion and equal in number to the number of rotor blades, an elastomeric bearing assembly located within each arm to support its respective rotor blade so that the rotor blade is capable, during operation, of flap, lead/lag and feathering movements, a gas charging valve attached to said rotor hub and in communication with the interior thereof so as to enable the hub structure to be pressurised, and a gas pressure indicator secured to said hub and arranged to provide a visual indication of any loss of gas pressure from the hub.

30. A helicopter rotor substantially as hereinbefore described and with reference to Figures 1 and 2 of the accompanying drawings.

31. A rotor as claimed in claim 30 and modified substantially as hereinbefore described and with reference to any one of Figures, 3, 4 or 5.

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1514347 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

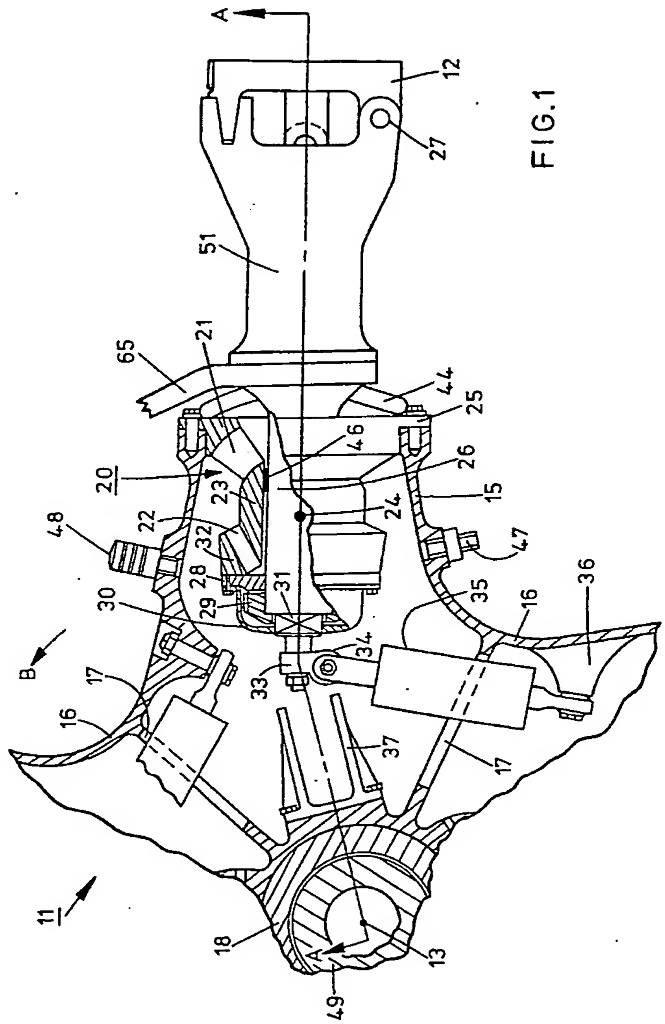

FIG.1

1514347 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

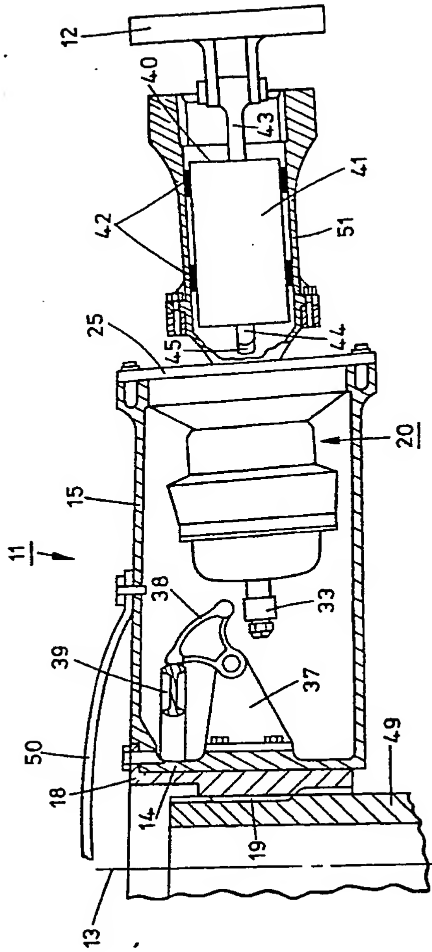

FIG. 2

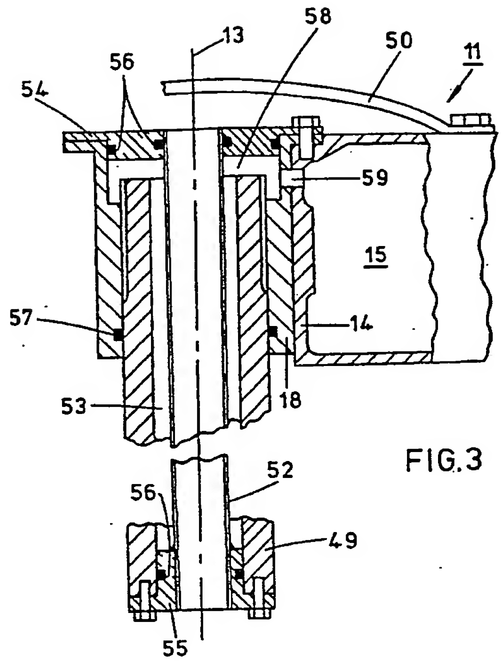

FIG.3

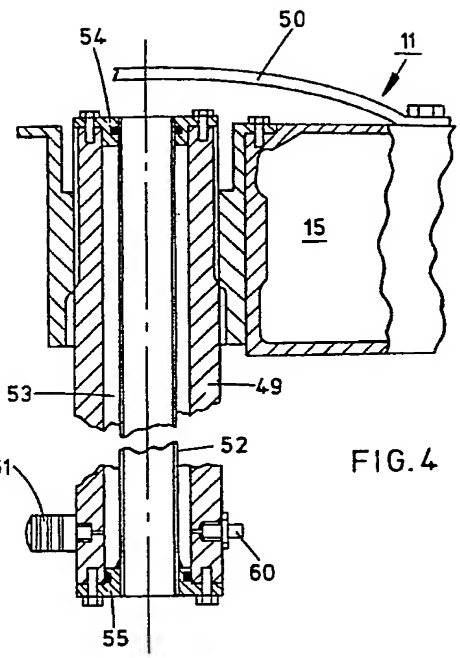

FIG. 4

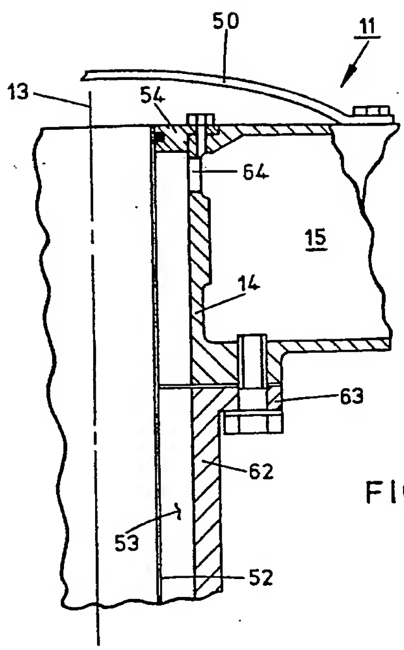

FIG. 5